

FILTERING MEDICAL IMAGE USING ADAPTIVE FILTER

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Abstract- To date various image filtering approaches are reported, most of them enhance the signal-to-noise ratio(SNR) in different levels with loss of some useful information. In this paper, an adaptive template filtering method is described which can be used to increase SNR and keep the important edge information of medical images. In the proposed method, for each pixel, an optimal template of different shape and coefficients is selected automatically depending on its neighbor pixels. Not being simple extension of the 2D method, sequential filtering of slices in three orthogonal directions implemented the 3D algorithm, which improved existing adaptive template filtering technique, avoiding a burden of enormous search. Simulation and MRI image tests ,both 2D and 3D, show that the new adaptive template filter provides higher SNR and sharper edges.

Keywords: Adaptive template filtering, magnetic resonance imaging, edge extraction

1. INTRODUCTION

In medical imaging, if the SNR is too small or the contrast too low it becomes very difficult to detect anatomical structures because tissue characterization fails. For a visual analysis of medical images, the clarity of details and the object visibility are important, whereas for image processing a high SNR is required because most of the image segmentation algorithms are very sensitive to noise. A major obstacle to segmentation by multiple thresholding or by multivariate statistical classification is insufficient data quality.

When developing a filtering method for medical image data, image degradation by blurring or by artifacts resulting from a filtering scheme is not acceptable. The following requirements should ideally be fulfilled¹:

- a. minimize information loss by preserving object boundaries and detailed structures.
- b. Efficiently remove noise in region of homogeneous physical properties, and
- c. Enhance morphological definition by sharpening discontinuities.

To date various image filtering approaches are reported, most of them enhance the signal-to-noise ratio(SNR) in different levels with loss of some useful information. In this paper, an adaptive template filtering method is described which can be used to increase SNR and keep the

important edge information of medical images. In the proposed method, for each pixel, an optimal template of different shape and coefficients is selected automatically depending on its neighbor pixels.

2. METHOD

In linear spatial filtering, the content of a pixel is given the value of the average brightness of its immediate neighbors. Simple spatial averaging, often called "low-pass filtering", does reduce the amplitude of noise fluctuations, but also degrades sharp details such as lines or edges. The filtering does not respect region boundaries or small structures, and the resulting images appear blurry and diffused. This undesirable effect can be reduced or avoided by the design of nonlinear filters². In digital image, edges are often relative with the local intensity gradient of the images, and can be extracted with the intensity gradient methods. The operator of intensity gradient mainly retains horizontal and vertical edges, whereas Roberts' operator can detect slanting edges in 45 or 135 degrees with the horizontal direction.

Another approach is adaptive filtering, which entails a tradeoff between smoothing efficiency, preservation of discontinuities, and the generation of artifacts. Generic images can be supposed as composing of some 2D or 3D limited regions, which are homogeneous or slow-changeable, and separated by discontinuous boundaries. The core of adaptive template filtering is to search a appropriate template, which best matches the limited homogeneous region enclosing the considering pixel . Using the template, the best filtering results can be obtained. The algorithm defined a set of templates. For a given pixel, its neighbor pixel may be classified as object or background. Totally, we have $\sum_{n=2}^9 C_8^{n-1} = 255$ templates. For the selection of the best template, the following two values must be calculated:

$$\sigma_j = \sqrt{\frac{1}{N_j - 1} \sum_{k=1}^{N_j} (I_k(x, y) - m_j)^2}, \quad (1)$$

$$m_j = \frac{1}{N_j} \sum_{k=1}^{N_j} I_k(x, y), \quad (2)$$

where N_j is the number of non-background pixels in template j, m_j is the intensity mean of pixels in template

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j , and σ_j is the standard deviation.

For MRI images, intensity variations in the limited homogeneous region of a template are mainly caused by random noise. Since noise of MRI image is independent of signal, the standard deviation is relatively small in flat template. For this region, a template should be chosen which has most number of non-background neighbor pixels, so that maximum noise suppression can be obtained.

$$T = \arg \max_{T_j} N_j \{T_j | \sigma_j < t\}, \quad (3)$$

Whereas in the edge region, the sharper change of intensity makes the standard deviation larger. An edge template with minimum standard deviation should be used:

$$T = \arg \min_{T_j} \sigma_j \{T_j | \sigma_j \geq t\}, \quad (4)$$

The use of a flat template or an edge template is determined by a threshold value t . In order to speed up the selection of the best template, we may start the calculation of the standard deviation for the template having most non-background pixels, then templates with lesser non-background pixels. The first found template which standard deviation is less than threshold value t is the best template. If all template's standard deviation are greater than t , then the template with minimum standard deviation is used.

Choosing the best template, the filter coefficients can be obtained by 2D adaptive least square error³:

$$T_{x,y} = \frac{\sigma_k^2(x,y)I(x,y) + \sigma_n^2m_j}{\sigma_k^2(x,y) + \sigma_n^2}, \quad (5)$$

$$\sigma_k^2(x,y) = \max(0, \sigma_i^2(x,y) - \sigma_n^2), \quad (6)$$

where $T_{x,y}$ is the filtered output. $\sigma_i^2(x,y)$ and σ_n^2 are input image variance at point (x,y) and noise variance of the image respectively.

Principally above mentioned method of 2D adaptive filtering can be extended to 3D volume data application. But in 3D case, the total number of possible templates is $\sum_{n=2}^{27} C_{26}^{n-1}$. The exhaustive search of the templates is almost impossible with current computers. We do not use the 3D templates for the volume dataset. Actually, for a given voxel, the 2D adaptive template filtering are performed in three orthogonal planes through the voxel sequentially. For MRI volume data, the whole brain can be thought of as a stacked slices. The three orthogonal planes are axial, cortical and sagittal slices. First, the slices in axial planes are filtered with the 2D adaptive template filtering algorithm, then filtered in cortical planes, finally in sagittal planes. We get good results of 3D filtering avoiding enormous computations.

3. RESULTS

To evaluate the algorithm we generate a simulated image on which there are some concentric circles and radiation lines(Fig.1, top left). With this image we can evaluate the algorithm by its ability of keeping edges in different directions. First we add Gaussian noise on the image(Fig.1, bottom left). Then two conventional filtering methods, Intensity gradient method and Roberts' filter, and the adaptive template filtering are applied to the image.

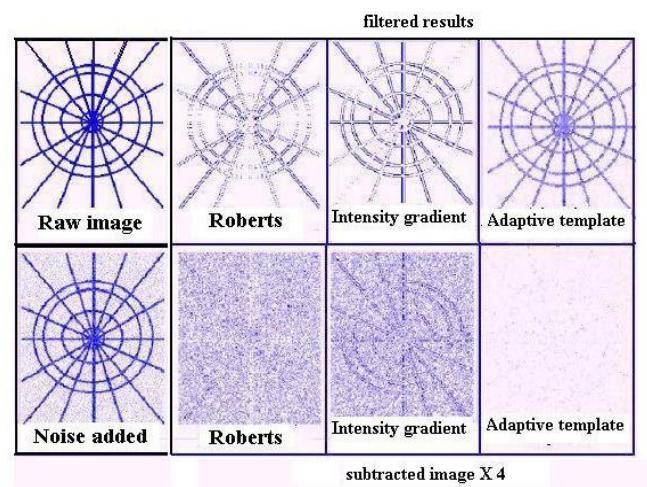


Figure 1. Edge extraction of adaptive filtering and conventional methods.
top:extracted lines,
bottom:subtracted images.

The comparison of the methods are shown in the top right of fig.1, from which we can see that the two conventional methods can only retain edges in particular directions, but adaptive template filtering keep the edges well in all directions. The lower right of fig.1 shows the difference images of the filtered and original images. Obviously, the proposed method has best filtering effect.

For the validation of adaptive template filtering algorithm with medical images, the MRI image data were downloaded from MNI's BrainWeb⁴, which has 181 slices, slice thick is 1mm. One healthy subject was scanned 27 times, and the acquired data were summed and averaged. The resulting image has very high SNR(fig.2,(a)). To test the performance of the filter, some Gaussian noise was added (fig.2,(b)). Fig.2,(c) shows that after adaptive template filtering, even the edges of some small anatomical structures can be seen clearly on the resulting image. The proper α value is also in the range of 0.8–1.2. Fig.2,(d) shows the difference image of images after and before filtering.

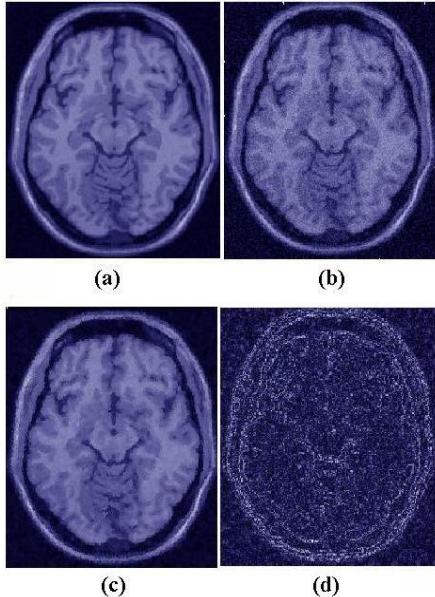


Figure 2. Filtered results of MRI image. a.Original image, b.Noisy image, c.After adaptive filtering, d. Subtracted image X 10.

Similar as in 2D test, the simulated 3D volume data constructs a sphere with thin surface. Originated from the sphere center there are many symmetrical radiation lines. Before filtering some random noise was added. Then the volume data were filtered slice by slice in three orthogonal directions sequentially using 2D adaptive template filtering algorithm.

We have also done the experiments for MNI 3D volume data using this 3D adaptive template filtering algorithm, and obtained good filtering results.

4. CONCLUSION

A novel approach to the noise suppression and edge extraction in medical images has been developed and tested. Unlike conventional filtering, where the template shape and coefficients are fixed, multiple templates are defined in the proposed algorithm. For each pixel, an optimal template is selected automatically depending on its neighbor pixels. The adaptive template implements best filtering of medical images. Simulation and MRI image tests, both 2D and 3D, show that with the new adaptive template filter the important edge information of medical images can be retained while eliminating noise. Not being simple extension of the 2D method, sequential filtering of slices in three orthogonal directions improved existing adaptive template filtering technique, avoiding a burden of enormous search.

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